# DOE_GDO October 16 NTP Study Webinar Transcript

WHITNEY BELL: Hello, and welcome to today's national transmission planning study informational webinar. I'm Whitney Bell with ICF, and I'll be your host today. First, we have a few housekeeping items for today's webinar.

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We will have time for Q&A after today's presentations. You may submit questions at any time using the chat function. Additionally, if you have any technical issues or questions, you may type them in the chat box and select Send to Host for assistance.

[INAUDIBLE] finally, in one of our most popular questions that we get, we will post a recording and a copy of today's presentation on the National Transmission planning study webinar web page by this Friday. We will alert you via email when those materials are available online. The link to that web page is in the chat now.

All right, with those announcements out of the way, let's get started. To kick off today's meeting, we'll hear from Maria Robinson, the Director of Grid Deployment Office, for some opening remarks. Maria, welcome.

MARIA ROBINSON: Thank you so much, Whitney, and welcome, everyone, to today's webinar. I'm Maria Robinson. I have the great honor of leading the Grid Deployment Office.

Part of our mission space is to catalyze the development of new and upgraded Electric Transmission infrastructure across the country by maintaining and investing in critical generation facilities, developing and upgrading high-capacity electric transmission lines nationwide, and deploying transmission and distribution technologies. We oversee more than $22 billion in funding that supports all of the above. In the two years since its creation, the Grid Deployment Office has committed more than $10 billion in funding for tribes, states, local governments, and private industry to advance a more affordable, reliable, and resilient grid.

During this period of time, we have also released the National Transmission Needs Study, which I suspect many of you are familiar with, our triennial state of the grid report. We finalized the federal rules to establish the coordinated interagency transmission authorizations and permits program and finalized a new four phase national interest electric transmission corridor designation process, as well as announcing a preliminary list of 10 potential [INAUDIBLE], as they're called.

We've also convened decision makers and stakeholders on the Atlantic and west coast to inform the development of recommendations for addressing near, medium, and long term offshore wind transmission challenges, and we have published a resulting Atlantic coast action plan for offshore wind.

In all of these efforts, the Grid Deployment Office has found that national grid scale transmission planning is incredibly important to our nation's future. Of course, the US transmission network is the backbone of our electricity system and delivers highly reliable, affordable electricity that ensures that lights stay on and businesses operate even during periods of extreme demand. Though the transmission system has certainly served our needs for more than a century, our country's needs are changing.

Our grid needs to be more interconnected than ever before to account for growing electricity demand, withstanding the impact of extreme weather, as our thoughts are with our friends in the southeast, connect new zero and low carbon energy resources to the grid, power new manufacturing enterprises and data centers, and enable vehicle and building electrification.

We believe that expanded transmission could enable additional opportunities for connecting and distributing already proposed generation projects, balancing the variability of wind and solar resources, and accommodate growing energy demands while maintaining system reliability and, of course, energy affordability. An expanded transmission system could also help to meet national energy objectives, supporting domestic manufacturing, and electrifying large parts of the economy and continue to serve the evolving energy needs of this century and beyond.

So today, you'll hear from experts from our office talking about the National Transmission Planning Study. The study finds that there are major benefits to transmission and expansion across the continental United States, focusing in particular on three areas. First, grid reliability-- improving inter-regional transmission, of course, can enhance grid reliability, particularly in response to those extreme weather events, as it allows more resources to be shared across regions and energy to be moved from where it's available to where it's needed.

Second, again on affordability, consumer savings-- a substantial expansion of the transmission system throughout the entire contiguous United States delivers the largest benefits to consumers and would save the United States somewhere between $270 and $490 billion through 2050 with about $1.60 to $1.80 in system cost savings for every dollar spent on transmission. And third, we found that expanded transmission enables the great connection of new generation projects, including new, cleaner generation onto the grid as it helps to balance the variability of wind and solar resources and accommodating growing energy demands while maintaining system reliability, so important, and energy affordability.

So we intend to move forward with this study now that it has been released to the world and put those findings to use in conjunction with the tools that we have developed with ongoing planning processes at the state, regional, and interregional levels, and we invite you to be a part of those processes, and we look forward to continuing our engagement with all of you. The National Transmission Planning Study, of course, led to the utilization, expansion, and creation of new and existing transmission planning tools, and we hope that planners across the country can leverage these tools to support their planning processes.

And of course, as states deepen their engagement in transmission, they can seek to use some of these specific capabilities developed under our studies and work closely with those of us here at the United States Department of Energy and our friends at the national labs. So with that, I'll turn it back over to Whitney, and looking forward to hearing from our experts at our national laboratories as well as here at the Grid Deployment.

WHITNEY BELL: Well, thank you so much, Maria. Really appreciate that quick overview. So now, we're going to hear from Patrick Harwood.

He's a general engineer and transmission planning with the Grid Deployment Office. He's going to provide a little bit more context around the study framework and some of the objectives. So Patrick, I'll go ahead and turn this over to you. Welcome.

PATRICK HARWOOD: Thank you, Whitney, and good afternoon, everyone. The DOE formally kicked off the National Transmission Planning Study in March of 2022. It's currently led by the Grid Deployment Office in partnership with the National Renewable Energy Laboratory and Pacific Northwest National Laboratory. The study builds on past projects and expertise of the DOE, NREL, and P&L.

In the NTP study, we sought to develop national scale transmission planning tools that can be used by industry, especially when playing for inter-regional transmission. We sought to identify some of the potential transmission solutions that will provide broad scale benefits under a wide range of potential futures. Further, we sought to inform existing planning processes for both regional and inter-regional transmission planning.

And finally, we were looking at the energy adequacy aspects of reliability in light of the nation's changing resource mix and seeking to identify how national transmission strategies can help maintain this adequacy. To focus in on those objectives, I'll highlight that the NTP study links several types of modeling analysis to test many transmission scenarios that may lie outside of existing utility planning practices. I want to emphasize, however, that the NTP study does not replace existing regional and utility planning processes.

Any transmission opportunities or results that we present today could be areas of further exploration, but they don't represent all possible solutions, nor should they detract from transmission projects already included in regional plans. The NTP study does not go into the detail of recommending any specific lines or the routes or locations or environmental impacts or plans of service. Hopefully, you've all had a chance to download and start reading the report. As you will see, it's divided into chapters based on the type of modeling analysis performed.

The introduction chapter explains the steady progression from wide area capacity expansion modeling with many scenarios, and that's in chapter two, to a selection of detailed production cost modeling simulations in chapter three. Further, a sample of cases for power flow and stress analysis or extreme weather tests are presented in chapters four and five. We've also included an executive summary and conclusions chapter, which explained the principal findings and key takeaways from each piece of the study, which we'll go over more on today's call.

Additionally, I'll just mention that leading up to the publication of this main report, the labs released three related reports shown on this slide. They were the Interregional Renewable Energy Zones report, or IREZ report, published in March, the barriers report published in June, and the western interconnection baseline study published last month. Thank you. I'll turn it back over to Whitney to introduce my lab partners.

WHITNEY BELL: Thank you so much, Patrick. As Patrick said, we now welcome our Juliet Homari, she's a systems engineer, and Nader samaan. He's a chief power systems research engineer-- they're both with Pacific Northwest National Laboratory-- as well as David Palchak, senior engineer for the transmission group at the National Renewable Energy Laboratory.

They will help us dive deeper into the study and share some key takeaways. So Juliet, let's go ahead and begin with you. Welcome.

JULIET HORNER: Thank you very much, Whitney. Hi, everyone. Pleased to be with you today.

I'm going to be talking about our stakeholder engagement and public outreach that we did as part of this study. We had four pillars to our outreach plan, and the first was we had a public input opportunities. We had four public meetings, including this one.

And we also had a comment form on the project website, where folks could add comments and feedback. Then we worked with existing convener groups, folks like the eastern interconnection planning collaborative, NARUC, the National Association of Regulatory Utility Commissioners, National Governors Association, and others. Probably the biggest part of our outreach strategy was through our technical review committee, or our TRC.

The TSC was comprised of three subcommittees. We had a modeling subcommittee, a government subcommittee, and a subcommittee on land use and environmental exclusions. And I'll talk more about that in the next slide. We also had designated tribal outreach as part of the study.

So, a little bit more on the meetings and the engagement. We had four public meetings over the course of this study. We had three meetings of our plenary technical review committee.

We had six meetings of the modeling subcommittee, four meetings of our government subcommittee, and then two meetings of our land use and environmental exclusions subcommittee. And we also hosted four rounds of regional meetings and then had two sets of office hours. So we appreciate all of you who participated in this study, either through meetings or through providing comments. And with that, I'm going to turn it over to David Palchak from the National Renewable Energy Laboratory to jump into the results and the key findings.

DAVID PALCHAK: Thank you, Juliet. Hi, everyone. Good afternoon. Thanks for being here.

So I'm going to talk about the general setup of this study as well as jump into some key findings. So what this slide shows is the general setup of the methodology for our study. It's kind of broadly divided into two sections-- the zonal resolution and the nodal resolution. In the zonal resolution, what we're looking at is long term scenarios through 2050, and that's kind of represented here with the map.

And you can see little kind of differences in the gray boxes. And so that's more or less the resolution of our modeling within the zonal resolution modeling, and that allows us to look at a lot of different scenarios, look far into the future, and do a lot of modeling on policies and technologies and different costs of assets for the grid. We then move into some of our nodal resolution model, and we do a deep dive on several of our scenarios.

And there, we're looking at 2035 scenarios. We call those 2035 transmission portfolios. And we're doing a deep dive asking a lot of questions about liability of the grid in the future. And altogether, this brings together a lot of different modeling and analysis. Ultimately, we're looking for low cost, reliable transmission system in the future, and this allows us to get a good picture of that, and it's a very comprehensive study.

These boxes at the bottom here represent more or less the modeling or the different parts of analysis. I'm going to spend a lot of time talking about what comes out of the capacity expansion model. So that's a model that allows us to look at these future scenarios, and it is optimizing the amount of generation, storage, and transmission in the system.

So I'll talk about a lot of the key findings from the capacity expansion, and I'll make it through most of the blue boxes and then a little bit into the green. And I'll turn things over to my colleague Nader to talk about some of the impacts to reliability, about these future systems. But overall, this is a pretty large effort, pretty comprehensive effort for transmission planning. And certainly, we think that this setup helps paint the picture for how transition planning could look in the future.

So, starting with our scenario, so as a transmission study, the transmission dimension of our scenarios is one of the most important parts. So we have four of those starting at the top with our reference transmission framework. We call that our limited scenario.

So what this is is a constrained scenario where we don't allow transmission to be built between regions. So you see in the map here, we have some black lines around the United States, and that divides the different planning regions. We divide this into 11 different planning regions so that these are roughly the FERC order-- 1,000 regions plus ERCOT.

And we allow transmission to be built within the regions in this scenario but not across those black lines, so not across regions. We also limit the total amount of transmission that could be expanded. So this is taking recent observed maximums for transmission expansion and extending that out into the future.

So we're essentially looking at historical rates of deployment in our limited scenario. So, kind of a constrained transmission system compared to our three accelerated transmission frameworks, the next three here. So we have three different flavors of this and alternating current.

So this is probably most like what might be happening on the system now, where we're mostly developing on AC transmission. So we're allowing expansion within the interconnection, so the three interconnections in the contiguous US or the lower 48. So we allow expansion within these interconnections. We don't allow any new DC connections, but we're essentially allowing as much transmission as is optimal to meet the needs of the system in our AC scenario.

The next two are two different flavors of HVDC expansion. So we have point to point and the multi-terminal. Both of these allow expansion of the transmission system across the entire country. In the point to point, we have long distance point to point HVDC options.

This is maybe more traditional HVDC that has been built, a few of these in the US at this point. And then our multi-terminal is, again, expansion across the entire country. But that includes multi-terminal HVDC options, and that's more of a meshed sort of network, and you can build HVDC between neighboring regions here.

So, two different types of HVDC. We'll broadly think of those as kind of our accelerated transmission frameworks, and that's probably how I'll mostly refer to them, and we'll oftentimes compare that to the limited, all three together.

So in addition to just our transmission frameworks, we also want to understand other things that we're not totally sure about. So we also have three demand growth scenarios-- so, low, a mid, and a high. So the low is essentially the historical rates of growth in electricity demand.

It's about a little less than 1% per year in our low scenario. In the mid, we are doing moderate electrification in this scenario. So we're changing both the total growth in demand as well as the shapes-- so, putting in electrification in line with recent-- so that would be IR incentives that are in this middle education scenario. So those are part of that electricity demand.

Our high demand scenario is looking at total electrification by 2050. So this is net zero for our total energy emissions by 2050, so very high electrification. These are roughly 1%, 2%, and 3% electricity demand growth out to 2050 per year.

So we also crossed out with three different emissions targets, the first one being the current policy. So that takes into account essentially the state policies that are put in place for emissions as well as other maybe federal incentives, like the Inflation Reduction Act, and other policies that were in place by last

summer. So that's kind of everything that was in the books last summer gets put in the current policies. We also have two more decarbonized scenarios.
So a 90% by 2035 CO2 reduction-- we'll call that usually 90% by 2035. So most of the electricity sector is decarbonized by 2035 in that scenario and then is fully decarbonized by 2045 and then an even more strict decarbonization policy of 100% by 2035. So that's the electricity sector there.
And the goal here, so we end up having 36 core scenarios, so when we cross all of these up. And the goal here is to understand the role of transmission across many possible futures, the role and value of transmission across these many possible futures. So that's our basic scenario framework.
We also want to test some of these general scenarios against other sensitivities, so things that we might be unsure about-- so, technology costs or technology availability. I'm not going to go into these too much today, but we do use these for some of the summary statistics that we'll talk about at the end. So it's good to know that we looked at a lot of different sensitivities here. And most of them have to do with cost and technology availability as well as some others, including a climate scenario. We're actually looking at climate impacted wind, solar, amp load in that scenario and trying to understand what is the role in value transmission there and is it a lot different than in our other scenarios.
So that's our general scenario framework. Now I'm mostly going to jump into the findings. So we're going to get into the results here.
So I'm going to walk through what is essentially the setup for our executive summary. So we have six principal findings that we talked about in the executive summary and 22 supporting key takeaways. We're not going to get to all of those today. But we will get through the principal findings and some of these supporting takeaways.
So the principal findings are divided into these categories. So we'll start with transmission expansion under current policies, and then we'll get into several topics that are mostly around the 90% emissions reduction. So we think of that as kind of our central scenario.
And we'll talk about the benefits of transmission, the amount of transmission expansion, greater reliability, and several pieces to that as well as some promising regional transmission, hopefully some starting points for industry and other stakeholders. And then we'll kind of finish off with some advancements and planning approaches that we developed through this study. OK, starting with current policies-- so again, to repeat this, so the current policies represents things that were in the books essentially since last summer.
Most of those are state renewable portfolio, clean energy standards, the Inflation Reduction Act. We don't have some of these nonbinding state targets or corporate targets, we don't have those in here, as well as maybe some newer policies that might impact renewables, like some Clean Air Act rules that were put into place since then. OK, principle finding one-- so the lowest cost US electricity system portfolios that meet future demand growth and reliability include substantial expansion in transmission.
So again, current policies, we're looking at, in our accelerated frameworks, 2.1 to 2.6 times growth in transmission from our 2020 systems out to 2050 compared to our limited, which is quite a bit smaller than that. So if we look at the blue line here, that's essentially showing us what we allow our limited case to do. And it's growing as much as it we allow it. It's constrained transmission in there as we allow transmission to be developed here in this middle plot. You can see the total transmission capacity, and we're essentially doubling or more of the transmission in these scenarios where we allow it to be built.

And this includes all transmission, so including local interconnection, regional, and interregional in this plot, the doubling of the transmission system or more when we allow it. The inter-regional transmission is shown here on the right, and that essentially is the transmission that's crossing from one color to the other color. So, crossing over transmission planning regions, and we'd see even bigger growth in these scenarios, especially in our HVDC scenarios. So we're seeing 1.9 to 3.5 times the amount of regional transmission compared to the limited in these scenarios. So, large transmission growth when we allow it, essentially.

And one of the benefits of that transmission growth is for emissions reduction. So in our accelerated frameworks, we're looking at 10 to 11 billion metric tons of reduced emissions by allowing more transmission to be built. So the transmission capacity here again in the middle of 2020 to 2050, if we look over to the right, we're looking at electricity sector CO2 emissions from 2000 to 2050.

And those black dots there at the top are showing historical emissions out to 2020. And then the colored lines are showing the modeled emissions, and it's divided into our four transmission frameworks here. So our limited is showing a sharp decline immediately but then kind of leveling off and reducing emissions. And then our three accelerated transmission frameworks continue to reduce emissions. And a lot of this is coming from access to wind and solar and being able to interconnect wind and solar to provide those resources around the country.

OK, so that's it for current policies. I'm going to move on to some of the central decarbonization scenario findings. OK, so again, the central decarbonization scenario, this is 90% emissions reduction by 2035, 100% by 2045.

It's implemented as a national target on power sector CO2 emissions. We do have some negative emissions technologies in certain scenarios, and it applies to upstream methane emissions as well. So the top box or the top kind of matrix in the top right here shows why we call it central decarbonization scenario. So this shows our different emissions constraints and demand growth scenarios.

And centered right in the middle here is this scenario I'll be talking about. And again, down at the bottom, seeing the emissions and the trajectories of emissions in our different scenarios-- so the 90% one on the right and then the 100% one, a very steep decline, on the left. But again, I'll be talking about the 90% one, the lighter brown.

OK, so, principle finding number two-- so the study finds hundreds of billions of dollars in net benefits from large scale transmission expansion compared to our historic rates of transmission [INAUDIBLE], so being our this scenario. And so just showing here, Maria talked about this a little bit. But ultimately, when we allow transmission to be expanded, we're getting a lot of savings.

So this plot is showing us the net present value of savings compared to the limited framework or total electric system cost savings through 2050. So we're looking at $270 and $490 billion in savings by allowing transmission to be built. And that equates to about 4% to 8% in our different scenarios or AC at 4% and then our MT or multi-terminal HVDC going up to 8%.

So what that ends up equating to in terms of benefit cost ratios, and this is something that Maria mentioned, is that in our core scenarios, there's approximately $1.60 to $1.80 saved for every dollar spent on transmission. And that comes from increased investment in transmission compensated by some of the reduced investment in fuel generation and storage capacity and other costs.

So essentially, transmission is showing that it's quite worth it in this expansion scenario. And if you look here, we're showing a summary of many different scenarios and sensitivities in our three different transmission frameworks, and the $1.60 to $1.80 or 1.6 to 1.8 is on the lower end of this. So our core scenarios are on the lower end of the benefit cost ratio.

Some of our scenarios and sensitivities have quite a bit higher benefit cost ratios. All of them in our 90% scenario showed benefit to cost ratios over 1.5. So certainly in the way we modeled this transmission certainly will be worth it from a benefit cost perspective.

Another finding within that savings is that as we move to higher demand scenarios as well as if we move to more highly decarbonized scenarios, we see a scaling in these savings that you get from transmission. So the savings that we just saw here is in the top middle. So the mid-demand, 90% by 2035 scenario, that's where we saw the $270 to $490 million in savings.

If we move to the right, all the way to the right, we see even more savings compared to the limited framework by building transmission. And then if we move down into our 100% scenarios, again, increasing the amount of savings, both with higher demand and with higher decarbonization. OK, so the next principle findings, so substantial expansion of the transmission system throughout the entire contiguous US-- so that's the lower 48-- delivers the largest benefits across a wide variety of scenarios. So here, we're mostly going to be talking about the scale. So we mentioned that a little bit, but starting with the savings, so we're saving money from transmission back to the scale. And again, this is different than the current policies that we looked at. We're looking at larger amounts of transmission in these scenarios.

So in the 90% scenarios, we're looking at an expansion of 2.4 to 3.5 times the size of the 2020 system by 2050. And these are in the scenarios that achieved the lowest total power sector costs. If we break that out and try to understand what types of transmission were built here, that's what we got plotted here on the right.

So this is transmission capacity for our four different transmission frameworks. So we kind of lost the writing on the first one. That's the limited framework.

So what we see there is a lot of the gray lines are being built out from 2020, and that means that spur and reinforcement is basically taking up the full capacity that we allow transmission to be built. So most of transmission that we allow in that scenario is being used for local transmission and so essentially interconnecting wind and solar as much as possible in that scenario. So that's a really important part of this throughout. Even though a lot of our findings are about long distance, high voltage transmission, a lot of the local transmission continues to be a big part of this story here.

As we move to the right, we see a lot bigger transmission. So we're getting over into the 2.4 and 3.5 times total transmission capacity. The local transmission, the spur and reinforcement, continues to be a very big part of this, an increasing part of this. But as we move over, we'll see a lot of AC transmission, built in AC, and then the HVDC scenarios, HVDC kind of crossing over into being the more cost optimal transmission choice in these later scenarios.

But certainly there looks to be that there's a lot of opportunities for HVDC, whether these are all HVDC options that should be pursued. But certainly a lot of opportunity that you can see here where HVDC would be used. And just to kind of finish defining the legend here, so the VSC, LCC, those are different types of HVDC technologies and back to back.

But broadly here, I think it's just important to note that ultimately, we're talking about HVDC scenarios and kind of a different paradigm in terms of the AC that we're looking at on today's system.

So taking that result and mapping it, you can actually see some of these trends around the country. We have five maps here. The existing system. Is shown on the top here, existing 2020 system.

So this is what it looks like in our zonal model. This is taking actual an transmission system and summarizing it into a zonal model. And then in our bottom plots here, you see the new transmission through 2050 for our four transmission frameworks.

And in the gray boxes, what you're seeing is the local interconnection capacity built within these zones. So that's built in all of these scenarios, and you see quite a bit built in some scenarios. If you're looking at our accelerated frameworks here, you can start to see a lot of different trends-- our AC in the top right point, and multi-temrinal on the bottom.

A lot of expansion of these long distance lines-- you start to see that trends even within all three of these, where a lot of it is in the central part of the country, as well as some other trends that you can probably start to pick up that start to identify themselves across all scenarios, even though the technologies are slightly different, certainly some kind of paths along the south and through the center of the country that seem to be common between all of these different scenarios. But all types of transmission and all around the country certainly see transmission development.

So just to reiterate, so the transmission capacity, as we saw in some other forms here, but to simplify, the transmission capacity here developed is 2.4 to 3.5 times bigger in these accelerated frameworks, and our HVDC scenario is showing a lot more transmission. So, a lot of opportunity for HVDC, particularly in the advanced voltage converters and a lot of savings. So these end up being the lowest cost systems as well.

OK, so moving on to some of the reliability takeaways, so grid reliability can be maintained in future low carbon grid scenarios with the lowest cost solutions relying on coordinated transmission utilization between regions, especially during periods of greatest stress. So, grid reliability is a big topic, and we try to tackle some of those within this study. I'll talk about a couple of them, but we certainly appreciate there's further things to be done in grid reliability, but do have some good takeaways here.

So again, just to remind you where we're at in terms of the modeling and the analysis framework, so we've talked about capacity expansion on the left, talked about a lot of those scenarios kind of in the resource adequacy box now. And I'll just spend a few slides talking about that before jumping into more of the nodal results. So, kind of a core takeaway is that all of this-- and we looked at 96 modeled features. That's our set of scenarios that we modeled out to 2050. And all of those, including ones very high levels of renewable energy, meet or exceed resource adequacy standards. So this is by design. We wanted them to meet resource adequacy standards.

But still, these are very high renewable energy scenarios, very different scenarios than what the system looks like today. So this confirmation and sort of validation that these systems can work, at least at the scale that we're modeling. So a good kind of solid base in the sense that these are adequate systems.

When we coordinate to achieve the resource adequacy that we get in these systems, we find that you can lower the system costs by quite a bit by coordinating between regions. So transmission obviously playing a big role in coordination between regions, being able to send our sometimes periods of greatest stress. And when we do that, we find that we can lower the total system costs by $170 to $380 billion.

And that's shown here in the plot. This is total savings when we allow resource adequacy sharing between regions. This is such a potentially important benefit for transmission in a value stream for transmission that when we ignore that or when we take out that value stream, we build substantially less transmission. And so by not including that within the benefit side of our benefit to cost ratio, less transmission makes sense in those scenarios. So an important value stream potentially for transmission research adequacy.

OK, so now we're starting to move into our nodal resolution modeling. So, been through a number of findings here, mostly in the zonal resolution, talking a lot about out to 2050. We're going to shift now a bit to talking more about 2035, some of these transmission portfolios, how we got there.

And an important part of that is this zonal a nodal translation.

So this is a pretty arduous process where we start to bring in a lot of the details of the power system and all of the transmission lines that you see on the highway and the substations outside of your towns. These are part of this nodal resolved model. So these are very detailed power system models, and we start to ask deeper questions about reliability and about how the system works and some of these engineering challenges and operational challenges that you might see in the future.

But the zonal to nodal translation is a big part of this as well, as there will be what we call production cost models. So that enables us to look the operations in the future. And while building those, so we ended up building-- this is an example of three different transmission portfolios for 2035, so the limited AC and the MT. I know these are small. We're not going to be able to go into these in too much detail today.

But they're certainly common themes when building out these transmission portfolios in detail. One, that there's reinforcements of the transmission lines occurring in most regions around the country-- so that was also seen in some of our zonal work where we looked at the local interconnection capacity. But certainly when we get down into the actual network topologies, certainly needing reinforcement all around the country as we start to build out a lot of wind and solar in these scenarios in some cases. Now additionally, increased meshing improves reliability or contingency performance, especially when we're building a lot of renewable energy in more concentrated areas of the country where the networks might not be as strong.

And then finally, I'll just skip to the last one here. So with some of the HVDC that we see in this MT HVDC, we still see a lot of AC. So these are quite ambitious scenarios in terms the amount of HVDC that would be built, but we still needed a lot of the AC to do a lot of the work, especially locally, to help bring resources to these HVDC transmission lines that could carry the power over longer distances.

So it looks like these certainly need to coexist and would need to be kind of planned together. So an important part of HVDC were it to take a bigger role in the future. So these list several common themes that we talked about. So this, we're kind of getting into chapter three now, and we also have several other lists about these nodal scenarios and the development of these network models, which hopefully is useful for industry planners.

Another thing that having these more detailed models helps us with is to ask, as we said, the kind of engineering challenges, operational challenges, making sure that we can balance supply and demand. So ultimately, we were able to demonstrate that demand and supply were able to be balanced in these power systems.

And these are very high share of renewables in these scenarios-- so, up to 90% in some. So, a good validation of these systems working in the future and hopefully some lessons learned there. So with that, I'm going to turn things over to Nader [INAUDIBLE], who is one of the technical leads on the study from the Pacific Northwest National lab.

NADER SAMAAN: Thank you, David. Hi, everyone. So I'm going to cover the next part of the nodal analysis, which is power flow. Power flow is a way for grid planners to check on the health of the grid, how reliable it is under normal operation and under contingency or outage operations.

So from production cost modeling, it's a way to mimic market operation. We can simulate a whole year, H7 60 hours, of generation dispatch and how different generation mixes are meeting demand at different hours at different seasons. From there, we can extract certain hours or snapshot of operation.

For example, we are interested in an hour somewhere where load is high and significant amount of load is supplied by solar or maybe another hour on the same day after sunset where significant amount of load supplied by wind and storage. So to do that, we are having a tool we call the choronological AC Power Flow Automated Generation Tool that will enable us to take any of those hours of interest from production cost modeling and import it into commercial tools that used typically by grid planner to do additional or more detailed reliability analysis.

So in particular here, which, this material is covered in detail in chapter four. We are looking to the outage of new lines. Like, we need to make sure these new lines, we need to make sure any of these lines are not representing a high risk to the system in terms of when they are in outage, like unplanned outage. And the other issue we'd like to show is, OK, if we have one of those power plant online is getting also an unplanned outage, which units online will be able to cover this outage?

So the main conclusion we have in our report is, yes, these new lines are not representing high risk. Even during when they are highly loaded and they are subject to unplanned outage, we still see the grid is operating in a reliable manner. And the other conclusion is storage will play a key role when you have a power plant outage storage online. Either in charging mode, acting as a load, it will help simply reduce this load.

So it will help to compensate for the generation loss. Or even if it is acting as a generator in discharge mode and it has enough room to move up, it can also quickly cover for the generation. So I'll just show you this couple of examples here.

So what you are showing here is a pre-contingency is one certain hours that we took from production cost modeling. This is around 10:00 PM, where significant amount of wind [INAUDIBLE] supply demand. And where you see the rectangular, this purple rectangular, is a power flowing from central New Mexico to south west of New Mexico.

And these are two new circuit, each loaded about 1,500 megawatts. So it's heavily loaded. And we'll see what the outcome or what the result if these two lines were subject to unplanned outage. So in the right side on the slide, you'll see this house, the grid, where the flows will be redistributed after the outage of this line.

So what you can see here, you will see more arrows with yellow, which means these are heavily loaded lines that are where the flow for these lines that are outage will be redistributed in these lines but still within acceptable limit for grid planner. You have certain limits under contingency that you say that's fine. So what you see here, it's a grid still operating in a reliable manner under even despite outage when this line is carrying a significant amount of power.

The other thing also, we can see a heat map in the left and right. Each heat map represent voltage profile around the grid of substation. So as long as it is green, that's, again, kind of a way to measure how well the grid is.

So you can see pre-contingency, both contingency. We still see the green everywhere, which means the grid still operating in a reliable manner in terms of voltage. Both closed and voltage are acceptable.

The other outage that, for example, we [INAUDIBLE] report is outage of two large units that account for about 2,600 megawatts. And this outage in particular happened in the morning hours in a summer day. And we are comparing here between three different cases.

The case in black or showing the bars in black, these are a business as usual industry based case versus two cases from the study. The one in the middle is limited, the one with the light blue is the inter-regional case. And what's interesting here in the base case, you can see hydro is playing a key role to provide the additional generation needed to recover for the generation loss.

Versus the [INAUDIBLE] case, we start to see storage is playing more important role. In this particular hour, storage was more in the charging mode. So it's acting as a load. So simply, if you have generation loss, you can decrease the load by decreasing the amount of charging to storage.

And the especially also in the inter-regional case where storage is more distributed. You have more larger footprint. You can take advantage of transmission. So storage will even play a key role taking advantage of transmission to provide for the loss of generation. That was one of the interesting outcome from this analysis.

Another part of the analysis which is covered in chapter five is the stress analysis by case, how these future grids will behave or will withstand extreme weather events such as heat waves, cold snaps. In this particular work, we only covered two events or mainly heat waves. And what we did, we looked to two heat waves that happened in 2015 in Pacific Northwest and one happened in 2018 in the South California and southwest and project this event to year 2075, taking into consideration the potential of climate change, which may result in higher temperature, higher demand.

And to make it even kind of the perfect storm, we combine that with kind of a below average hydro year, which means hydro generation will be below average, which means generation availability is lower. So it's kind of a perfect storm for grid planners. And look how the system-- will the system instead be able to meet demand during this event?

So what we found here, that-- and here, I'll focus on the events that happened in California. What you see here is the amount unserved with load. So the more black or the more dark colors, that means you have more significant unserved with load. And the graph or the map on the left is a limited case versus is the one on the right is the inter-regional case.

So you can see the inter-regional case, overall, it has less amount of unserved energy, which means inter-regional transmission helped to support load in California and reduce the amount of unserved energy during this extreme event. So that was one of the takeaways that grid planner should take into consideration when evaluating the new transformation, how this new transformation may help to go through or mitigate the extreme event or answer [INAUDIBLE] during the extreme event.

Another piece of takeaway here is this kind of extreme event analysis is very data intensive. You have to look to historical event, project it to the future. The project team develop a lot of tools that can be leveraged by grid planners.

So they can use it in their future transmission planning to be-- so stress analysis will be part of their normal part of their transformation planning process. And [INAUDIBLE]. Yes, I will give it back to David so he can cover the [INAUDIBLE] transmission part. Thank you.

DAVID PALCHAK: Thanks, Nader. So I'm going to talk about a couple of the promising candidates that we looked at through the study. So, trying to really simplify, I know we've kind of thrown a lot at you at this point.

But I promise there are some simplifications in terms of the messages and so our chapters in our executive summary here to try and make some of this a little bit more tangible. So the first way we did that was we looked at high opportunity transmission. We call these the hot interfaces.

So this is us trying to take all of these different scenarios and summarize it down into essentially what is the capacity that shows up in a lot of these different scenarios. And the way we did that, as we said, what is the new transmission capacity in at least 75% of the sensitivities across our transmission frameworks? And that's what you see here representing in the maps.

I know this is probably hard to see, but these are available at higher resolution in the executive summary in chapter two. But what we hope this kind provides is that these are robust. These maps are robust solutions that we see across a lot of different futures and are potentially starting points for planners and developers to pick up those capacities as potentially plausible in the future.

So we have these for each of our different transmission frameworks for the 90% scenarios. So that's one way we kind of tried to summarize this. Another is something we talked about with transmission portfolios. So these are scenarios that are providing broad scale benefits to consumers using the lab and industry tools. Certainly, they demonstrate that inter-regional transmission and intra-regional transmission upgrades can help meet the flexibility requirements for these high renewable systems. So again, these are 90% decarbonized systems by 2035.

And so certainly, there's some ideas here, some solutions that we hope can be used by industry and developers and other people thinking about the development of the electricity system. But kind of as a caveat, these are not proposed routes or detailed siting considerations. We don't have that level of information, or at least we're not able to use [INAUDIBLE] when we're looking across the whole country. So these are not exact maps or are not looking to replace the planning, as Patrick mentioned, that needs to happen down within the regions, within the utilities. But certainly, we hope there are a lot of promising solutions here that can be used by the industry.

And finally, we had a lot of development of different tools and data to do this study and certainly kind of recognizing that regardless of all of these different scenarios and the policy and the market and the technology conditions to be able to plan at a national or regional scale does require a lot of coordination. And that certainly is not just the coordination needed for things like resource adequacy. We had a key finding on that.

That's at a certain type of coordination. But there's additional coordination on the planning side to think about, the data that's needed, the grid modeling approaches. And hopefully, through this NTP study, we've developed some of those methods, and hopefully, everyone is finding that useful to go through the chapters, and we're happy to work with you in the future to transfer some of these tools and data that we've developed and can hopefully be good partners going forward.

So with that, I'm going to turn it over to Jeff Dennis from the Grid Deployment Office

JEFF DENNIS: Thank you very much to David, Nader, and everyone at our national lab partners who did such great work on this groundbreaking study. You heard all of those tremendous results, all of the tools that we've developed. It really is incredible, groundbreaking work, and I couldn't be prouder of them and prouder of our partnership here. So, thank you.

If we jump to the next slide, what I want to just briefly highlight from the Grid Deployment Office perspective is our sincere and keen interest in turning these findings into action. As it's been mentioned-- David mentioned it. I know others have mentioned it as well.

These findings are instructional. They're illustrative. But we understand that where these findings will really have meaning is when they are adopted in real planning processes on the ground.

Those planning processes held at the regional level, held at the local level, and in a regional planning processes as well are all where the real work will be done here going forward to make sure that we can turn some of these findings and some of these benefits to customers into action. So we're working now to share the findings and analytical tools that have been developed here with transmission planning entities, RTOs and ISOs, utility transmission planners, as well as our partners in the States because ultimately, we want this work to help advance beneficial transmission planning for consumers. In addition, we are working to encourage examination by planners of those high opportunity transmission options that you saw a little bit earlier in the presentation.

Again, as our lab colleagues mentioned, these are areas where are under a variety of different scenarios in the future, there are potential transmission options here that under a variety of these scenarios would provide benefits to consumers and warrant further study by industry. And of course, we want to continue to use these studies going forward in additional transmission planning study work that we will do.

Our 2026 National Transmission Needs Study, that's the triennial study that we do under the Federal Power Act, this will be an important input to that. And it will help us as we think about how to best use other tools that Congress has given us, whether it's future rounds of the transmission facilitation program or work to designate national interest electric transmission corridors. These study findings will help with all of those. It won't directly dictate applicant selections, but it will help us shape programs, will help us really work with applicants on where we think applicants would be most beneficial to the public.

But they won't directly dictate our selections. Do want to be clear about that, any of these financing programs. Next slide, please.

In addition, I do want to highlight that DOE has a number of different technical assistance programs available that can help various entities engage in transmission planning. I won't go through them all here, but you can see them all. More information is available on our website.

You just saw a link pop up in the chat there. We have a couple of things, obviously, the Grid Resilience Technical Assistance Program that state energy offices, public utility commissions, and utilities can all partner in. A recently expanded program, the tribal nation transmission program, that is where tribal nations can come and help us with-- come and seek help from our national labs and from DOE to engage more in transmission planning and transmission facilitation efforts.

Really, I want to highlight that. That program originally started with offshore wind. We recently expanded it to cover transmission across the country, and it's been tremendously successful.

And we are also continuing to work on additional technical assistance opportunities to help states engage in transmission planning, capitalize on the new roles that have been opened up for them by FERC's recently issued order number 1920, and we'll be issuing more information about those opportunities in the near future as well.

Again, all of these opportunities, many, many more details on our website. You can also reach out to us. But did want to highlight those because these are ways that you can seek additional support from DOE and from the labs to take the results of this study and turn it into action on the ground. Thank you very much, and I think we are going to switch to Q&A now.

WHITNEY BELL: That's correct. Jeff. Thank you so much. So as you said, we are now to our Q&A portion of the webinar.

So please continue inputting your questions into the chat. We've received so many so far. We did want to let you know that questions may be combined if they are similar to avoid responding to duplicate questions.

We will do our best to address the relevant points in our responses. Any questions that we did not get to today during the Q&A session may be used to update the FAQ. So let's go ahead and get started.

And if we can bring our other panelists up, if you could turn on your cameras again, that would be great. We'll bring you guys here on screen for everybody. So it looks like our first question is for David. So David, the first one here, it says, did you take into account demand growth resulting from data centers, AI, Bitcoin mining, et cetera?

DAVID PALCHAK: So we did not explicitly take that into account. But we are looking at-- part of the reason we have three demand growth scenarios is because that is an unknown, and those things change quickly. But we are looking at, our highest demand scenario, we're looking at almost 3% growth per year, which far exceeds what we've seen in the past few decades.

So in some sense, we are taking new account very high demand growth but explicitly looking at AI or some of these other technologies, data centers. We didn't explicitly do that, but we think we probably captured the total amount of demand growth within our three demand scenarios.

WHITNEY BELL: Thank you so much. Nader, this question is for you. For simultaneous severe weather events captured-- for example, hurricanes in the Southeast, heat waves in the west, et cetera.

NADER SAMAAN: Yes, we have the capability to do that as long as that we are modeling kind of a time series, like, or the same weather pattern. So for example, you have a heatwave on a larger footprint, and on the same time some event happened far away. As long as it's captured in the same way as our model, yes, we can to play back this weather model projected to the future.

And it is kind of impacting, like, wind speed, solar irradiance temperature which impact events. So as long as that something happened in the past year, we can mimic it back in the future. But if something didn't happen in the past, yeah, I doubt we can mix and match with the pattern together to come up something unique.

WHITNEY BELL: Thank you for further explaining that. This next question is also for you. Is the CPH tool open source or to utilities?

NADER SAMAAN: Yes, it's not-- like [INAUDIBLE] typically, we'll be able to give a free research license to grid planners, utilities. So yeah, so we can-- it's not like open source available for download, but through this license, we can share it and give maybe some technical support, very limited technical support, to that to start using it.

WHITNEY BELL: Thank you so much.

NADER SAMAAN: Yeah, yeah. So yeah, if we contact me, I could help with that.

WHITNEY BELL: Yep, and we can try to get that person in touch with you. So then this question is for David. And I did want to say if there are any slides, you all need us to go back and reference, we are happy to go back into the presentation and do that to answer any of these questions. So, are savings on the order of single percentage values, the 4% to 8%, statistically significant given potential cost variations?

DAVID PALCHAK: So, to help maybe some other attendees who don't remember, so the 48% refers to the total savings that we saw in our 90% scenarios. So that was the net present value savings we saw in the accelerated transmission framework. So the way we look at this is really by having all of these different scenarios as part of our analysis.

And when we see consistency between those scenarios, especially when we're changing the technology costs or changing the PV and wind costs, the transmission costs, seeing consistency in the savings direction across these scenarios, that really indicates to us that these are significant and in the right direction. Certainly, we don't know all the costs of everything we put into the model 30 years into the future. But that's part of the reason we ran so many models is to try to continue to validate at least the direction and the relative cost savings we see. So the multi-scenario analysis is a big part of confirming for us that these results are in the right direction.

WHITNEY BELL: Appreciate that clarification. Another question for you-- are the benefit cost ratios based on savings through 2050 or the lifetime of the transmission asset?

DAVID PALCHAK: So these are based on through 2050.

WHITNEY BELL: Great. Jeff, this question for you. Given the significance of HVDC, please discuss what is entailed in the significant HVDC build out. Are utilities capable and open to HVDC buildout, and what are the biggest obstacles to HVDC buildout?

JEFF DENNIS: Sure. So, high voltage direct current technology can be very valuable and useful for a lot of the reasons that you've heard earlier. It's highly controllable. You can move a lot of energy with less losses.

So it provides a lot of benefits to consumers. But because it is a different technology than the alternating current, that technology that makes up most of our transmission grid, it does require certainly planners have to model it differently given its different characteristics. It does-- you do need to model additional impacts on the AC system, make sure those are all accounted for when you're modeling and planning HVDC.

And then operators, of course, need to account for it differently in their operating plans. And in particular, I would point to the controllability of this type of technology and other things. If operators take that into account, it can be extremely beneficial in extreme weather scenarios and other things like that.

But those are some of the considerations that go into planning and then operating HVDC. We are seeing industry very interested in further adoption of HVDC. In DOE's recent selections in our transmission facilitation program, 720 new miles of HVDC were selected.

So that would be a significant increase in what we see in HVDC today. So that shows industry's openness to it and willingness to construct it. Another challenge that industry and DOE is focused on is the supply chain for HVDC technology.

Certainly, the HVDC converter stations that are necessary to deliver energy off an HVDC facility and onto the network, we do have supply chain constraints in those and HVDC cables. But DOE and the broader federal government continue to work on improving those supply chains as is industry. And as we see more of these projects under construction, that will help further build out that supply chain here in the US.

WHITNEY BELL: OK, thank you. That was several questions in one. So I appreciate you in combining the answer. All right, David, It's kind of a two part question, but I'm going to go ahead and read both because you may be able to answer both in one answer here.

So the first question is, how are the costs of transmission buildout accounted for in this scenarios? Does it matter who pays the cost with respect to the effectiveness of any scenario? And then the second one is, can you clarify how much of the approximate savings in building new transmission is captured by consumers in comparison to transmission developers, utility industry, and how is that determined? If you need me to read any of that, please let me know.

DAVID PALCHAK: I can try and answer part of that. Yeah, so the transmission costs are-- we use a cost optimization. Also, these are compared to other assets that would help meet electricity demand.

So generation, storage, and transmission are all what I would call optimized together. And these are compared against each other to come up with total electricity system costs. So we have an input cost for transmission.

I can't remember the number of the top of my head. But ultimately, we have input costs on the technology costs for all of these different technologies, and they're weighed against each other to help meet demand at a certain place. In terms of how this actually gets passed to consumers, that's outside of the scope of this study.

But ultimately, the electricity system cost is typically passed to consumers in different ways depending on where you are in the country. But through your electricity bills, you might see a transmission charge or some other charges on the bill. So ultimately, all the electricity system costs do come from the consumers.

But overall, most of the time, what we're looking at is the lowest cost systems. And so how those costs get translated into consumers is kind of beyond the scope of this study. But we're trying to find the lowest cost solutions for all of these.

WHITNEY BELL: Great. Thank you so much, Nader, this question is for you. What recommendations are there for reinforcement of grid resilience and reliability in the face of climate change-related impacts of the hurricanes and extreme storms?

NADER SAMAAN: I think the first piece is to understand, let's say, to perform this kind of stress analysis, to understand the weakness of the grid and, again, if this event happened again in the future, where we have significant amount of wind, solar storage, and demand, how transmission can play a role to help with that. So I'd say it's more simulating of more of this event and try to different solutions which, I'd say, trying to figure out how different-- how to take advantage of diversity.

So if one area was high pressure, no one's showing up. maybe another area have significant amount of wind, they can-- so the wind can move from one area to another and so on. So I'd say it's more analytics, more analysis.

And then the other big point here, we maybe differentiate between transmission and distribution. So most of the time, the damage will happen in the distribution side, and versus transmission, which is the backbone, maybe not as much impact. So that should also be taken into consideration.

WHITNEY BELL: Thank you. Appreciate it. David, this next question is for you. Does the study have specific transmission capacity needs in each RTO outlining specific projects that could be competitively solicited?

DAVID PALCHAK: The short answer is no. That's beyond the scope of this study. We hope that the high opportunity transmission and the transmission portfolios provide insights for all the regions around the country and certainly willing to continue working with regions to try and pull out results of the study that can help direct kind of additional study or further study. But we're not kind of in the-- we're not looking for actual transmission lines as we kind of mentioned a couple times and certainly not thinking about the competitive solicitation side. Hopefully, we can bring a lot of solutions to the table here, and they're valuable to everybody.

WHITNEY BELL: Thank you. We do have one more question for you here, David. Did you specifically examine the potential of GATs to increase capacity with less need for new transmission lines?

DAVID PALCHAK: So, to some extent, I think we did. I would say probably not to the extent that a lot of interest within the industry is right now. We didn't explicitly look at GATs as a solution, but during our zonal to modal translation, we did take into account, existing corridors that would have capacity, and certainly any of the capacities that we talk about when we look at specifically the zonal results, any of those capacities that we talk about between regions or between balancing areas could potentially be met by GATs.

And that would probably be lower cost than the way we modeled it, which was to build new transmission lines. So certainly, it's not fully outside of the scope of this study, I would say. I think there's still insights for where GATs could be and reconductoring and other kind of new technologies might be helpful here. But certainly at the capacity level, I think we have those insights in the zonal model. The cost would be lower potentially if we looked at GATs or reconductoring. So I think there's insights here for that sort of analysis.

WHITNEY BELL: Great, and this is our last question for our time today, but do these models take into account utilizing the interconnections from retiring fossil generation assets for new clean generation?

DAVID PALCHAK: I'm sorry, Whitney. Could you repeat that one?

WHITNEY BELL: Absolutely. Did these models take into account utilizing the interconnections from retiring fossil generation assets for new clean generation?

DAVID PALCHAK: Yeah, so we do look at potentially transmission capacity that's available within the system from retired plants or other deactivated capacity. So yes, that's certainly taken into account.

WHITNEY BELL: Great. Thank you. [INAUDIBLE] you all for all your answers today, and Thank you to our attendees for all of your excellent questions. And that's all that we have time for.

So as a reminder to all the attendees, we will post a recording and a copy of today's presentation on the webinar web page for this Friday, and we will alert you via email when those materials are available. The link to that page will be in the chat momentarily.

Maria, Patrick, Juliet, David, Nader, and Jeff, thank you so much for joining us, and thank you to all of our attendees for participating today. Take care, everyone, and we'll see you next time.